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Comparison of free-field and earphone hearing thresholds

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1. Introduction. Hearing thresholds are standardized for free-field exposure [1] and for earphone exposure [2], [3]. The free-field thresholds are specified in terms of sound pressure level, before the subject is introduced in the field. Earphone thresholds are given in terms of equivalent thresholds, the sound pressure level measured in a coupler, when the earphone is supplied the voltage corresponding to threshold. Quite naturally, thresholds are different for each of these conditions. For earphones even several sets of thresholds exist, each valid only for a specific combination of earphone and measurement coupler. The thresholds given in the quoted standards are shown in Figure 1.

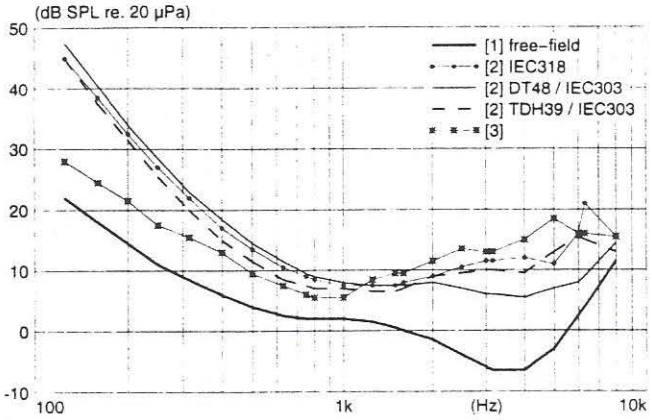

Figure 1. *Hearing thresholds given for various exposure situations.*

It is quite rationale to believe that the hearing threshold in terms of sound pressure level at the eardrum, is the same whatever the signal source is. It is the aim of the present investigation to establish a connection between the various descriptions of hearing thresholds.

2. Method. It had been shown earlier that the sound transmission to the eardrum from the entrance to the ear canal is independent of the sound source [4]. It was therefore chosen to refer all hearing thresholds to the sound pressure level at the entrance to the ear canal. For 12 subjects free-field hearing thresholds (T_f), and equivalent coupler thresholds (T_c) for six audiometric and audio earphones were determined in the frequency range 125 Hz to 8 kHz. All thresholds were monaural. For the frontal direction, individual head-related transfer functions (HTF) to the ear canal entrance were measured as well as individual transfer functions (PTF) of the earphones to the ear canal entrance. Furthermore, the earphone transfer function at the coupler (PTF_c) was measured.

Two terms exist for the hearing threshold referred to the ear canal entrance:

$$T_f \cdot HTF \quad \text{and} \quad \frac{T_c \cdot PTF}{PTF_c} \tag{1}$$

3. Results. For each subject (and frequency) one value exists for the left term, and six values exist for the right term, one for each headphone. The seven thresholds will be compared for individuals as well as for the group of subjects. The analysis has not been finalized at the time of submission.

References

[1] ISO 389-7 (1996) Acoustics - Reference zero for the calibration of audiometric equipment. Part 7: Reference threshold of hearing under free-field and diffuse-field listening conditions.

[2] ISO 389 (1991) Acoustics - Standard reference zero for the calibration of pure-tone air conduction audiometers.

[3] ISO 389-2 (1994) Acoustics - Reference zero for the calibration of audiometric equipment. Part 2: Reference equivalent threshold sound pressure levels for pure tones and insert earphones.

[4] D. Hammershøi, H. Møller "Sound transmission to and within the human ear canal", to be published in J. Acoust. Soc. Am.